Singletrack: Roadmap for a System for Integrated Modeling of the Atmosphere (SIMA)

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On behalf of the *SIMA Steering Group*

NCAR
NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

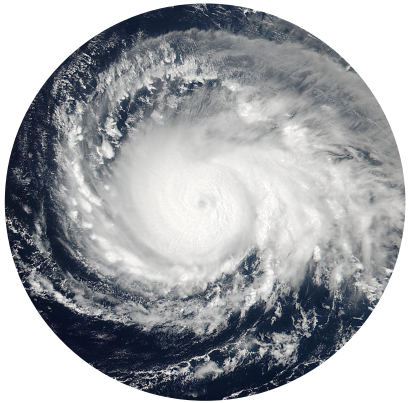
NSF

Current Community Atmosphere Models

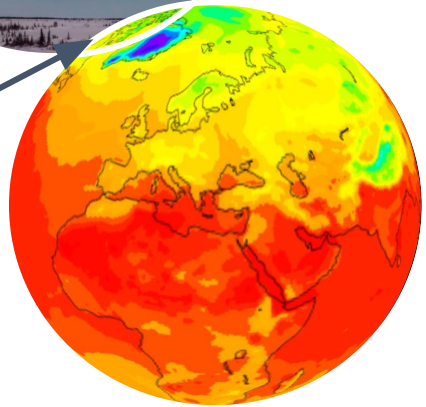
Existing Applications

Weather (WRF & MPAS)

Geospace (TIE-GCM)



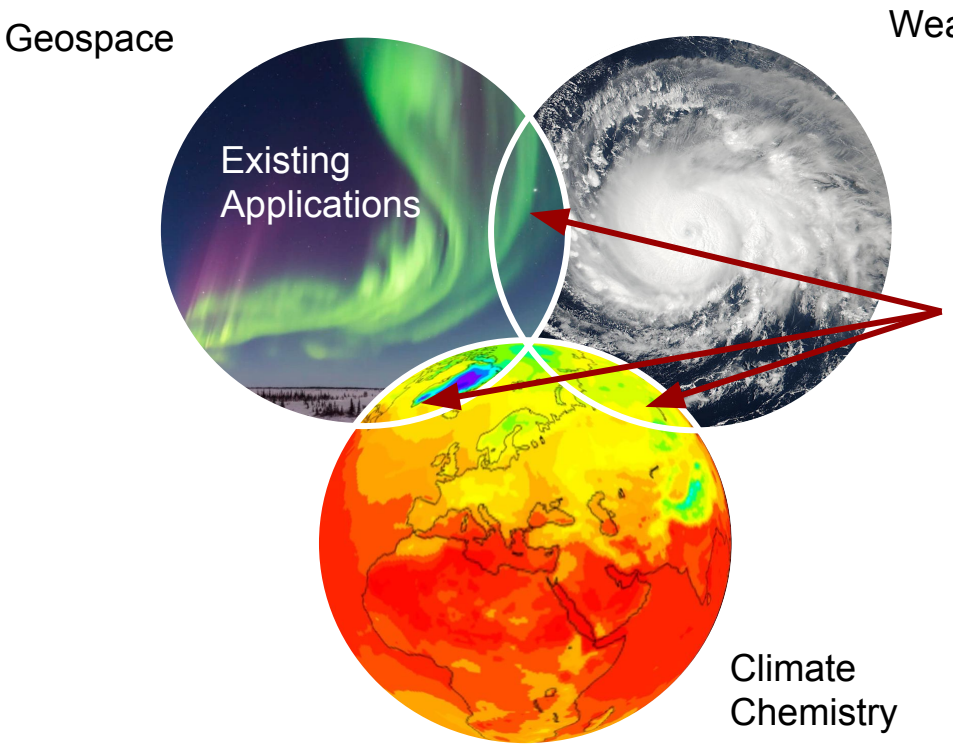
WACCM-X



Climate (CAM)
Chemistry (WACCM/CAM-CHEM)

SIMA Vision

Support Existing and Frontier Applications



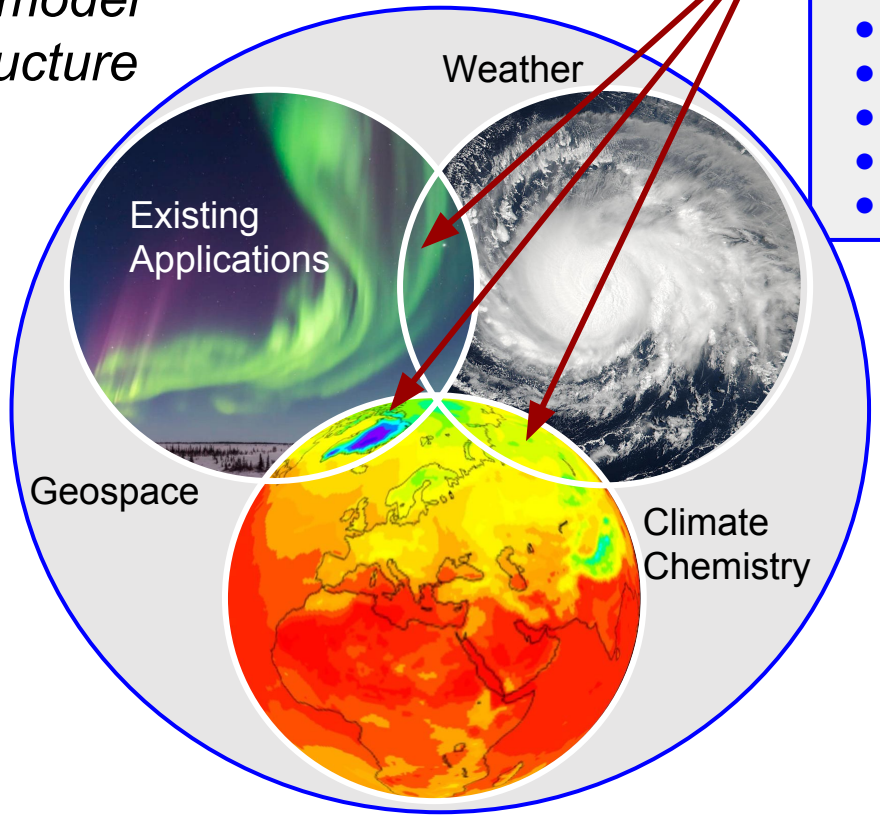
Frontier Applications

- Coupled Weather
- Climate Extremes
- Space Weather
- Air Pollution

System for Integrated Modeling-Atmosphere (SIMA)

SIMA is composed of common atmospheric model components & infrastructure

- Dynamical cores
- Physics/Chemistry
- Initialization
- Diagnostics
- Coupled System



SIMA Frontier Applications

- Coupled Weather
- Climate Extremes
- Space Weather
- Air Pollution
- Coupled Polar

Singletrack/SIMA Vision

Singletrack is the project to develop a roadmap for an atmospheric model system (SIMA)

SIMA Vision: An integrated global & regional atmospheric modeling system capable of simulating cloud to global scales in a community earth system model

- Encompass Climate, Weather, Chemistry & Geospace Applications
- Prediction (Initialized and Forecast) capabilities
- Complement & extend existing applications (CESM/WRF/MPAS)
- Shared infrastructure for efficiency and a minimal set of components

SIMA vision is aligned with 2018 NCAR advisory panel and 2017 NSF Site Visit Team (SVT) recommendations, and next NCAR Strategic Plan. Consistent with development goals for CESM (prediction, high resolution) & WRF (coupled)

SIMA Vision is Comprehensive

System for an Integrated Model of the Atmosphere (SIMA) Includes:

- Infrastructure: Robust infrastructure, usability from small to exascale, eliminate redundancy, consolidate and simplify around best practices
- Dynamical Core(s): Support applications, and development (geospace)
- Physical Parameterizations: Maintain ‘Suites’, aim for cross-scale physics
- Chemistry & Geospace: Links to physical model + specialized modules
- Prediction: Enable Data Assimilation, better initialization
- Diagnostics/Obs: Community Diagnostics, Facility Instrument Simulators
- Education/Training: Tutorials, Visitor Programs, Suite of simple models

Timeline

Past, Present, Future

'Singletrack'

- Jan-February: Organized, developed science goals, requirements
- March-May: Development of application examples, vision, outreach
- June: Discussions with NSF, WRF/CESM Communities
- July-Aug: Develop a 'Roadmap', Solicit Community Feedback
- Sept-Oct: Roadmap available. More feedback (CESM/UCAR Members)
- Oct-Dec: Invite Community Members. Refine SIMA plans/tasks

SIMA

- 2019-2021: Implementation: Phase 1 ≈ CY19, Phase 2 ≈ CY20, etc
- Oct 2021: Target applications in SIMA framework (end of CY21)

Community Development Process/Feedback

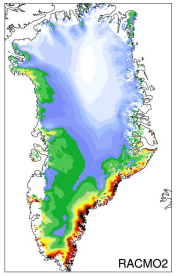
- ‘Management’ Feedback: UCAR Board, NSF Program Managers
- Community Feedback
  - Apr: Key Stakeholders (18 ‘Community Champions’) 11 Unique US Univ
  - June & October: CESM SSC
  - June: CESM/WRF meeting sessions (~200 people listening)
  - July/Aug: General Community Feedback
    - 43 replies, 16 US Univ (21 Unique Univ Total)
  - CESM Atmosphere Working Group (AMWG) webinar (54 participants)
  - UCAR Members Meeting: Strategic Planning discussion
- Initial feedback results:
  - Broad Acceptance of Frontier Goals: positive feedback
  - Cautionary Feedback Themes: One infrastructure good, not one model
  - Management feedback: want external advisory group

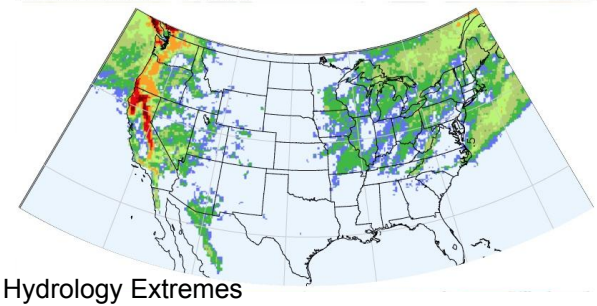
Frontier Science Goals

Map to specific applications

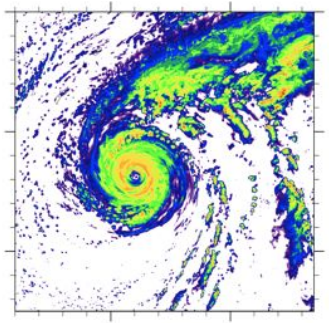
- Coupled Simulations at the Weather Scale
  - Tropical cyclones, Extreme convection, Urban pollution
- Extreme weather under climate conditions
  - Extreme heat and precipitation, extreme weather under climate change, air quality
- Polar Processes and Prediction
- Integrated Geospace modeling
- Regional/Urban Air Quality

Polar



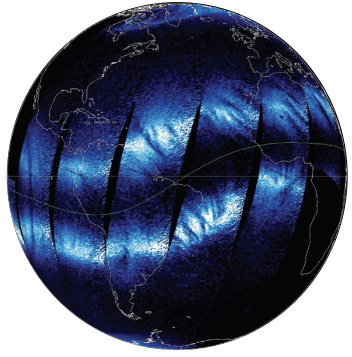


Hydrology Extremes



Tropical Cyclones

Air Quality



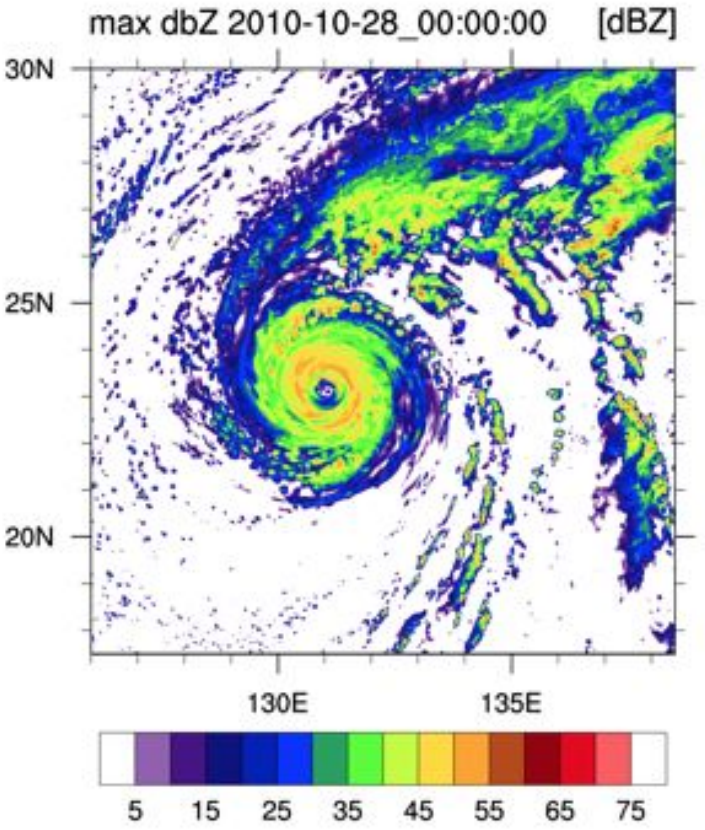
Space Weather

Applications: Weather

Tropical Cyclones

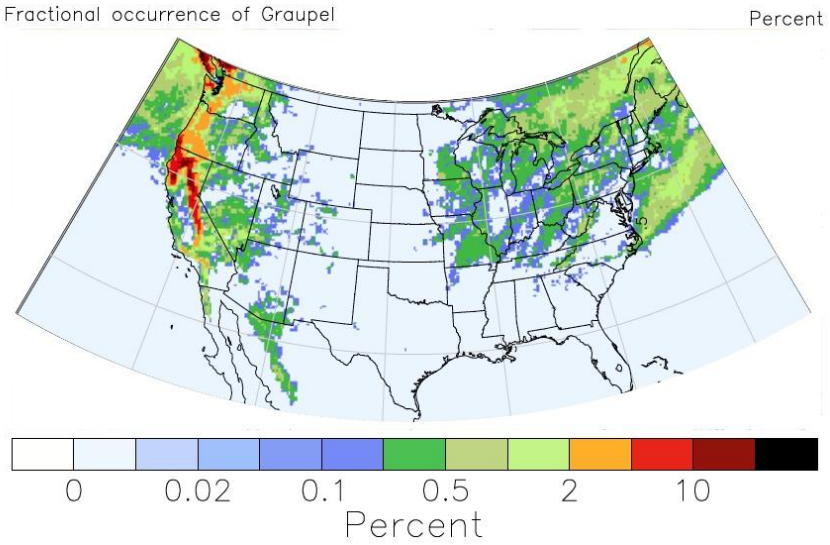
Simulate coupled weather phenomena in a coupled system at high (<5km) resolution. Example: tropical cyclones.

Also applies to MCS (convection) and S2S sub-seasonal prediction (MJO)



Applications: Climate
Hydrological Extremes

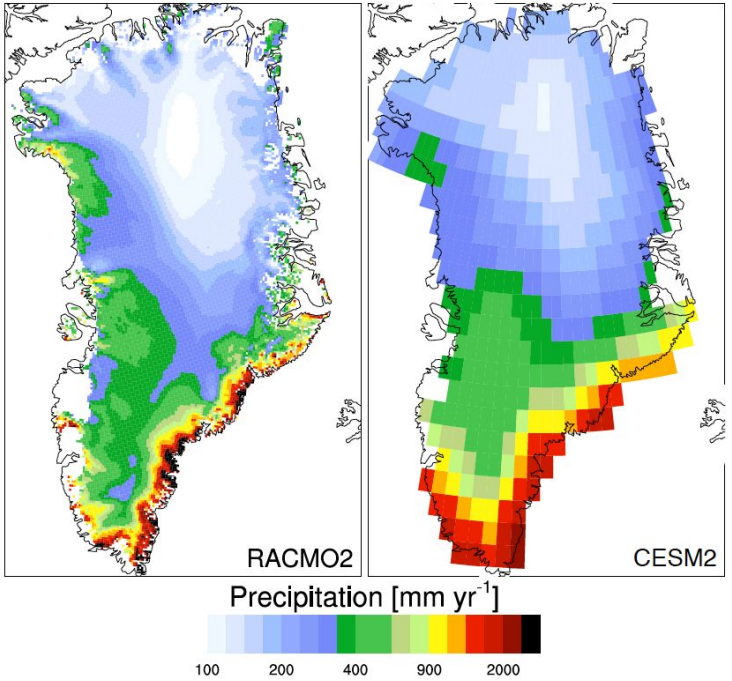
Simulate high impact weather extremes in a coupled system at high (< 5km) resolution. Example: occurrence of graupel (extreme precipitation) in a 14km global model



Also applies to floods, hydrology, droughts (up to seasonal). Prediction as well as climatologies of extreme hydrological events

Applications: Polar

- Simulate evolution of the Arctic environment
- Requires high resolution, but also a coupled system (especially to the cryosphere and ocean)
- Seasonal to Sub-seasonal (S2S) scale, but also Decadal scale

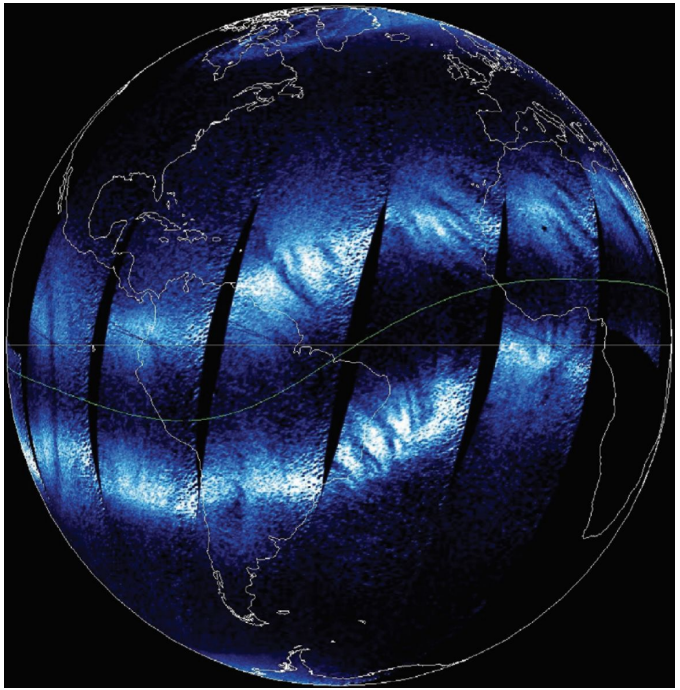


Target applications: 5km refined mesh forecast, 10-25km climate simulations. Coupled ocean, land, sea ice, land ice.

Applications: Geospace
Space Weather Prediction

Simulate forced events in the upper atmosphere that affect human systems and climate. Example: Ionospheric plasma bubbles that disrupt radio waves (Communication, navigation)

Couple specialized geospace models on different grids to a deep atmosphere model



Applications: Chemistry

- Represent air quality in urban regions
- Interactions between atmospheric chemistry, weather and climate

Requires chemical modeling at fine horizontal (< 5km) and vertical (multiple layers in the urban canopy) resolution within a global modeling system.

Delhi, March 2018

SIMA Frontier Science Applications

3 year Targets

Frontier	***Target Application***	***Configuration***
Weather	Tropical Cyclones	3km refined mesh, coupled ocean, initialized
Climate	Hydrologic Extremes	10km refined mesh climate simulations, 3km global initialized tests
Polar	Coupled Arctic System	10km coupled Arctic refined mesh
Geospace	Space Weather Prediction	25km global atmosphere to the ionosphere
Chemistry	Regional Air Quality	10km refined mesh with chemistry

Integrated modeling (SIMA) and CAM/CESM

- Existing *Science Goals* and *Applications* will be supported
- SIMA will support climate and earth system science
- CESM (AMWG/SSC) maintains control over its model configuration
  - SSC involvement and feedback on SIMA governance
- SIMA is a system to build different model configurations (CESM decides)
- CAM is a SIMA configuration
- SIMA target applications are priorities for CESM Working Groups
  - AMWG, WAWG, Chem-WG, PolarWG
- SIMA will improve CAM/CESM capabilities

SIMA benefits for CAM/CESM

"What if I just want to do current CESM applications (1˚)?"

- Non-hydrostatic dynamical core for high resolution
  - Better simulation of extremes, high-resolution
- New Chemistry and Geospace capabilities
- Better testing of physical parameterizations across scales
  - Improves traceability of physical parameterizations
  - Reduce tuning needed for different (including low) resolutions
- Improved usability, flexibility for research & simplified configurations
  - Improve ability to design experiments
  - Reduce complexity of input data across CESM (regridding)
  - Add to CESM 'simpler models' toolkit
- Improved access to and development of community diagnostics/tutorials
- Improvements for prediction
  - Initialization, nudging, data assimilation
  - Enables better S2S, Decadal Prediction, Hindcast, Forecast

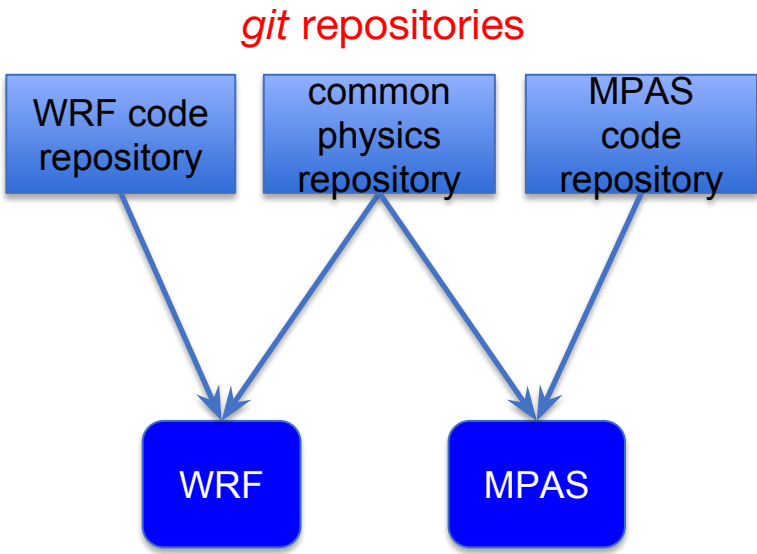
Integrated Modeling (SIMA) & WRF/MPAS

"What if I just want to do current WRF applications (20km regional)?"

- WRF will have greatly expanded capabilities
  - Coupled (and earth system) modeling, physics suites valid for any regime
  - Enhanced prediction capabilities (especially longer term, S2S and beyond)
  - Expanded community diagnostics packages
  - Heirarchial suite of models from single column, LES, idealized physics to global
- Maintaining existing capabilities: mesoscale, regional modeling
- WRF can access global physics suite through common physics framework
- Continue to support stand-alone MPAS until all MPAS applications can be achieved within SIMA
- Continue active support of WRF for very-high res limited-area applications

WRF/MPAS Consolidation and SIMA

- Physics
  - Common repository for physics
  - Compatible with CPF (in progress)
- Initialization
  - DART for initialization for both WRF and MPAS
  - MPAS initializing of WRF
- Common Postprocessing
- Support: online forum for WRF and MPAS
- Coupled modeling enabled for weather and regional climate (MPAS)



SIMA = *Community* Atmosphere Modeling

- Community engagement in planning, definition, applications
- Education/Training/Tutorial components
  - New science areas for early career scientists
  - Facilitate broader community interactions with modeling scientists
  - Access and training on new model developments
- A model for research and education: Simplified configurations
- Improved usability for focused problems (regional weather, idealized)
- Common interfaces/infrastructure to aid community development
- Diagnostic tools to incorporate observations & facilitate analysis
- Community governance: Weather & climate components